

Atty. Docket No. PPW06-560DS (OPP031047US)
Application No: 10/751,172

Remarks

Claims 1-7, 9-14 and 17-23 are active in this application. No claims were added or canceled in the present Amendment.

Applicant and his representatives wish to thank Examiner Lee for the thorough examination of the present application and the detailed explanations in the Office Action dated May 31, 2006. Also, Applicant and his representatives wish to thank Examiner Lee and Primary Examiner Lindsay the professional and courteous discussion held with their undersigned representative on October 17, 2006. Claims 1 and 17 have been amended as discussed. Also, as explained by the Rule 132 Declaration submitted with the Amendment filed March 15, 2006, the claimed invention provides unexpected improvements in processing time savings and resistivity. The following remarks shall further summarize and expand upon topics discussed.

The present invention relates methods for fabricating a semiconductor device, generally comprising:

- a) cleaning a semiconductor substrate with a transistor formed thereon, the transistor including a source electrode, a drain electrode and a gate electrode;
- b) placing the cleaned semiconductor substrate into a sputter chamber in a deposition equipment, and heating the semiconductor substrate to a temperature of from greater than 450 to 600°C;
- c) initially forming a monosilicide at the same time as sputtering a metal film at a DC power of 2 – 10kW under a state where the semiconductor substrate is heated at the temperature of from greater than 450 to 600°C;
- d) removing residual metal film not used for the formation of silicide; and
- e) annealing the semiconductor substrate (see amended Claim 1 above).

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The present Claim 17 contains similar limitations, but the semiconductor substrate can also be heated at a temperature of 450°C, and the silicide formed in step b) has a 1:1 metal:silicon ratio.

As discussed in the Declaration of Jae-Won Han filed on March 15, 2006, experiments were performed to determine the processing time savings provided by the present invention, as compared to a conventional process reasonably close to the present invention. Also, experiments were performed to demonstrate the improvement in contact resistance provided by the present invention. Finally, the Declaration of Han includes an explanation of the commercial importance of the results provided by the invention, to support the patentability of claims 1 and 17 as set forth above. Thus, the present claims are patentable over the cited references.

The Rejection of Claims 1, 2, 12, and 14 under 35 U.S.C. § 103(a)

The rejection of Claims 1, 2, 12 and 14 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka (U.S. Pat. No. 6,337,272) in view of Raajmakers (U.S. Pat. No. 4,908,331) is respectfully traversed.

Hamanaka relates to a method of manufacturing silicide, including the steps of forming a transistor on a substrate (see, e.g., Hamanaka, col. 11, ll. 57-61), removing a native oxide film from the surface of the substrate (see, e.g., Hamanaka, col. 12, ll. 7-10), placing the semiconductor substrate in a sputtering apparatus (see, e.g., Hamanaka, col. 12, ll. 10-12), forming silicide while sputtering metal and heating the substrate (see, e.g., Hamanaka, col. 12, ll. 12-26), removing the unreacted and partially oxidized metal (see, e.g., Hamanaka, col. 12, ll. 62-66), and performing an annealing process (see, e.g., Hamanaka, col. 12, ll. 66-67). Hamanaka discloses heating the semiconductor substrate, while depositing metal, at temperatures of 200°C (col. 12, ll. 13-15), 450°C (col. 8, ll. 43-48), or between 300°C and 400°C (col. 12, ll. 38-43). Hamanaka fails to disclose or suggest depositing a metal film while the semiconductor substrate is heated at a temperature of from greater than 450°C to 600°C.

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Hamanaka, however, is silent with regard to the sputtering power level. As a result, Hamanaka neither appreciates nor suggests the improvements in contact resistance provided by present invention (see, e.g., paragraphs 10-11 of the Declaration of Han filed March 15, 2006). Similarly, Hamanaka fails to appreciate the potential time savings provided by the present invention.

For example, after sputtering cobalt on the substrate while heating the substrate at a temperature from 200 degrees Celsius to 500 degrees Celsius, cobalt deposited on the N type gate electrode 205a, the P type gate electrode 205b, the N type source/drain region 209 and the P type source/drain region 210 chemically reacts with single crystalline silicon or polysilicon to form a dicobalt monosilicide (Co_2Si) film 212. Portions of the dicobalt monosilicide film 212a formed on the P type gate electrode 205b and the P type source/drain region 210 further chemically react with silicon to produce cobalt monosilicide (CoSi).

As discussed in the Declaration of Han filed March 15, 2006, experiments were performed on 24 substantially identical silicon wafers (i.e., one lot) to determine the processing time savings provided by the present invention, as compared to a conventional process reasonably close to the present invention ("Prior Art") and within the sputtering temperature range disclosed by Hamanaka (see paragraph 5 of the Declaration of Han). The "Prior Art" process sputtered cobalt at 200°C and subsequently formed silicide at 500°C, consistent with the disclosure of Hamanaka, whereas the process representative of the present invention sputtered cobalt at 500°C, in the lower half of the temperature ranges disclosed in Claims 1 and 17. Except for the Co sputter deposition step and the existence (or lack of) cap metal sputter deposition and silicide formation steps, processing conditions for the "Prior Art" process and the present invention were substantially the same. In the "Prior Art" process, forming a TiN cap/barrier layer was necessary because the wafers had to be transferred to a Rapid Thermal Processing (RTP) chamber for silicide formation (see paragraph 6 of the Declaration of Han).

As shown in the table in paragraph 5 of the Declaration of Han, the present invention enables reducing the number of steps in the silicide formation process by 25% and the amount of

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time by 33%, both somewhat surprising results given the reasonable expectation that the invention would enable reduction of only one step in the conventional process (silicide formation; see paragraph 7 of the Declaration of Han), rather than two steps as observed. Another unexpected result from the present invention is that the present invention enables use of the RTP equipment for other processing (such as implant diffusion and activation) that would otherwise be used for silicide formation. This unexpected benefit is commercially very important when a semiconductor wafer fabrication facility (commonly referred to as a "Fab") is capacity-constrained, because it enables other wafers to be processed more quickly as well (see paragraph 9 of the Declaration of Han).

In addition, two experiments were performed to form a metal silicide film, using the same processing equipment and the same recipe, except for the DC power (see paragraph 10 of the Declaration of Han). The results were as follows:

Sputtering Power	Silicide Resistance
2 kW	2.1 ohm/sq
8 kW	1.8 ohm/sq

Based on his experience in the field of semiconductor devices and manufacturing, it is Dr. Han's opinion that a manufacturing process that forms a metal silicide at less than 2 kW would likely not have a sufficiently low resistance to be commercially valuable. In other words, while such silicides could be expected to provide functional integrated circuits, such integrated circuits would be expected to have sufficiently high contact resistance (where the contact includes the metal silicide) to prevent the integrated circuit from exhibiting or achieving a commercially valuable signal processing speed (sometimes known as a "bin," which is frequently characterized by the length of time that a signal travels from input pin to output pin on the integrated circuit; see paragraph 11 of the Declaration of Han filed March 15, 2006).

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Thus, Hamanaka neither suggests nor appreciates the improvements in processing time and contact resistance provided by present invention. Raajimakers fails to cure these deficiencies of Hamanaka.

Raajimakers discloses a method of manufacturing a semiconductor device by depositing metal on semiconductor maintained at a temperature to form silicide (Title). According to Raajimakers, cobalt or nickel is deposited while the semiconductor body is heated to a temperature at which cobalt or nickel silicide is formed. Thus, metal silicide does not grow over parts of the regions of insulating material adjoining directly the regions of silicon (Abstract).

Raajimakers teaches that cobalt disilicide is formed directly if the temperature of the semiconductor body is higher than 500°C during the metal deposition, while nickel disilicide is formed directly if this temperature is higher than 750 °C (col. 2, ll. 40-44). In fact, Raajimakers appears to teach away from the present invention:

"It should be noted that during the formation of cobalt or nickel monosilicide silicon atoms diffuse more rapidly through the metal silicide than the metal atoms. This form of metal silicide is not obtained, however, if during the deposition the temperature of the semiconductor body is sufficiently high." (Col. 2, ll. 34-39 of Raajimakers.)

Thus, the combination of Hamanaka and Raajimakers would lead one of ordinary skill in the art to form a *disilicide* as a result of sputtering metal onto a heated substrate to form silicide, rather than a *monosilicide* or silicide having a *1:1 metal:silicon ratio*, as presently claimed.

However, assuming for the sake of argument that one of ordinary skill in the art would look beyond Raajimakers' teaching away from the present "monosilicide" or "1:1 metal:silicon ratio" limitations, Raajimakers is silent with regard to the DC power applied during sputtering of the metal. Thus, Raajimakers cannot cure the deficiencies of Hamanaka with regard to the improvement in contact resistance provided by the present invention and the commercial importance of such improved results, directly resulting from sputtering a metal film at a DC power of 2 - 10kW, as recited in Claims 1 and 17 above (see, e.g., paragraph 11 of the Declaration of Han filed March 15, 2006).

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Therefore, Claims 1, 2, 12 and 14 are fully patentable over Hamanaka in view of Raajimakers. As a result, this ground of rejection is unsustainable, and should be withdrawn.

The Rejection of Claims 3 and 4 under 35 U.S.C. § 103(a)

The rejection of Claims 3 and 4 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of in view of Raajimakers and O'Brien (US 6,458,711) is respectfully traversed.

As explained above, the combination of Hamanaka and Raajimakers is saliently deficient with regard to the results provided by the presently claimed invention. O'Brien fails to cure these deficiencies.

O'Brien relates to a method of forming silicide, including the steps of sputtering metal onto a substrate, and, in a separate step, inserting the coated substrate into a nitrogen atmosphere and raising the temperature to 600°C to create silicide (see, e.g., O'Brien, col. 2, ll. 54-62). O'Brien further discloses stripping residual metal (i.e., metal not used for the formation of silicide) with an SC1 solution (see, e.g., O'Brien, col. 3, ll. 40-55).

O'Brien forms silicide by heating the substrate to 600°C *after* sputtering metal onto the substrate. Furthermore, O'Brien is silent with regard to the sputtering power level. Therefore, O'Brien fails to cure the deficiencies of Hamanaka and Raajimakers with respect to the present claims and the results provided thereby. Thus, no possible combination of Hamanaka in view of Raajimakers and O'Brien can suggest or render obvious the present claims, and the rejection of Claims 3-4 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and O'Brien should be withdrawn.

The Rejection of Claims 5-7 and 10 under 35 U.S.C. § 103(a)

The rejection of Claims 5-7 and 10 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Sumi (US 6,022,805) is respectfully traversed.

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As explained above, the combination of Hamanaka and Raajimakers is saliently deficient with regard to the results provided by the presently claimed invention. Sumi fails to cure these deficiencies.

Sumi relates to a method for removing native oxide on a silicide layer after the formation of the silicide (see, e.g., Sumi, col. 3, ll. 54-61). Sumi teaches that the silicide is formed by the conventional method of heating the substrate to 600°C *after* sputtering the metal (see, e.g., Sumi, col. 1, l. 65-col. 2, l. 2). Furthermore, Sumi appears to be silent with regard to the DC sputtering power level (although various RF and microwave power levels are disclosed). Therefore, Sumi fails to cure the deficiencies of Hamanaka and Raajimakers with respect to the present claims and the results provided thereby.

Thus, no possible combination of Hamanaka in view of Raajimakers and Sumi can suggest or render obvious the present claims, and the rejection of Claims 5-7 and 10 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Sumi should be withdrawn.

The Rejection of Claim 11 under 35 U.S.C. § 103(a)

The rejection of Claim 11 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Wake (US 6,725,119) is respectfully traversed.

As explained above, the combination of Hamanaka and Raajimakers is saliently deficient with regard to the results provided by the presently claimed invention. Wake fails to cure these deficiencies.

Wake relates to a process for designing a cleaning apparatus line configuration in a process for manufacturing a semiconductor device (see, e.g., Wake, col. 7, ll. 30-32), including an apparatus for cleaning semiconductors comprising silicide (see, e.g., Wake, col. 9, ll. 16-18). Wake teaches that the silicide is formed by the conventional method of heating the substrate to after sputtering the metal (see, e.g., Wake, Background, col. 3, ll. 25-30). Furthermore, Wake is silent with regard to the sputtering power level. Therefore, Wake fails to cure the deficiencies of

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Hamanaka in view of Raajimakers with respect to the present claims and the results provided thereby.

Thus, no possible combination of Hamanaka in view of Raajimakers and Wake can suggest or render obvious the present claims, and the rejection of Claim 11 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Wake should be withdrawn.

The Rejection of Claim 13 under 35 U.S.C. § 103(a)

The rejection of Claim 13 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Wang (US 5,780,362) is respectfully traversed.

As explained above, the combination of Hamanaka and Raajimakers is saliently deficient with regard to the results provided by the presently claimed invention. Wang fails to cure these deficiencies.

Wang discloses a method for forming cobalt disilicide structure on a silicon substrate comprising the steps of depositing a cobalt layer on the substrate, thereafter depositing a refractory metal on the cobalt layer, thereby forming a bilayer structure on the substrate, and heating the bilayer structure (Abstract). Wang appears to be silent with regard to the sputtering power level. Therefore, Wang fails to cure the deficiencies of Hamanaka in view of Raajimakers with respect to the present claims and the results provided thereby.

Thus, no possible combination of Hamanaka in view of Raajimakers and Wang can suggest or render obvious the present claims, and the rejection of Claim 11 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Wang should be withdrawn.

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The Rejections of Claims 9 and 17-23 under 35 U.S.C. § 103(a)

The rejection of Claims 9, 17-18, 21 and 23 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Fortin (US 2003/0148606), and the rejections of Claims 19, 20 and 22 as being unpatentable over Hamanaka, Raajimakers and Fortin in further view of Sumi, Wake or Wang, are respectfully traversed.

As explained above, the combination of Hamanaka and Raajimakers is saliently deficient with regard to the results provided by the presently claimed invention. Fortin fails to cure these deficiencies.

Fortin discloses a cobalt silicide fabrication process, in which cobalt is formed on a wafer, then titanium is formed over the cobalt, and the wafer is heated to react the cobalt with the silicon. Then the titanium and the unreacted cobalt are removed (Abstract). Fortin teaches sputtering at a target power or DC power of 2 kW (Tables 1-2, following paragraphs [0019] and [0022], respectively). However, Fortin does not teach or suggest that the DC power has any effect or influence on the contact resistance of a structure containing a metal silicide formed by a process that sputters the corresponding metal at such power. Therefore, Fortin fails to cure the deficiencies of Hamanaka in view of Raajimakers with respect to the process recited in the present claims and the improved results provided thereby.

Thus, no possible combination of Hamanaka in view of Raajimakers and Fortin can suggest or render obvious the present claims, and the rejection of Claim 13 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Fortin should be withdrawn.

As explained above, Sumi, Wake and Wang are each silent with regard to sputtering at a DC power. Consequently, Sumi, Wake and Wang cannot cure the deficiencies of the combination of Hamanaka, Raajimakers and Fortin with regard to the present claims and the improved results provided thereby.

Consequently, the rejection of Claims 9, 17-18, 21 and 23 under 35 U.S.C. § 103(a) as being unpatentable over Hamanaka in view of Raajimakers and Fortin, and the rejections of

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Claims 19, 20 and 22 as being unpatentable over Hamanaka, Raajimakers and Fortin in further view of Sumi, Wake or Wang are unsustainable, and should be withdrawn.

The Rejection of Claims 2-4, 11-14, 18 and 21-23 under 35 U.S.C. § 112, First Paragraph

The rejection of Claims 2-4, 11-14, 18 and 21-23 under 35 U.S.C. § 112, first paragraph, is respectfully traversed.

The specification discloses forming CoSi, a monosilicide (by virtue of the presence of one Si atom in the chemical formula), in paragraphs [0013] and [0034]. Claim 2 as originally filed discloses "silicide with a composition ratio of CoSi." The term "composition ratio" unambiguously implies the existence and/or possibility of other species. For example, such other species could have the same ratio of cobalt and silicon atoms (e.g., CoSi, Co₂Si₂), or a different ratio of cobalt and silicon atoms (e.g., Co₂Si, CoSi₂). Thus, the application as filed supports the limitation "comprising CoSi."

However, the language of Claims 14 and 16 as originally filed ("wherein the silicide [...] *comprises* a composition of CoSi₂"; emphasis added) is much more explicit. There can be no reasonable basis for asserting that the application as filed does not support a limitation in which a silicide comprises CoSi₂.

Consequently, Applicant's undersigned representative respectfully requests withdrawal of this ground of rejection.

The Objection to the Specification

The objection to the specification is respectfully traversed.

As described above, the specification discloses forming CoSi, a monosilicide (by virtue of the presence of one Si atom in the chemical formula), in paragraphs [0013] and [0034]. Claim

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2 as originally filed discloses "silicide with a composition ratio of CoSi." Thus, the application as filed supports the term "monosilicide."

Consequently, Applicant's undersigned representative respectfully requests withdrawal of the objection to the specification.

Conclusions

In view of the above amendments and remarks, all bases for objection and rejection are overcome, and the application is in condition for allowance. Early notice to that effect is earnestly requested.

If it is deemed helpful or beneficial to the efficient prosecution of the present application, the Examiner is invited to contact Applicant's undersigned representative by telephone.

Respectfully submitted,



Andrew D. Fortney, Ph.D.
Reg. No. 34,600

THE LAW OFFICES OF
ANDREW D. FORTNEY, PH.D., P.C.
401 W. FALLBROOK AVE., SUITE 204
FRESNO, CA 93711

ADF:adf